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Connecting Distributed Energy Resources to the Grid: Their Benefits to the DER Owner/Customer, Other Customers, the Utility, and Society

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Engineering Science and Technology Division
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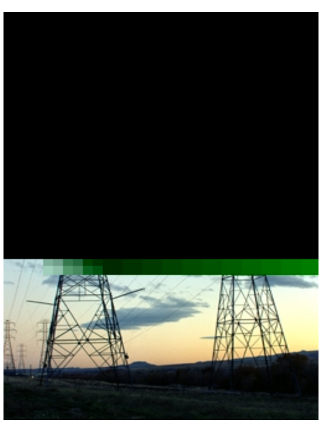

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4. SUMMARY OF SURVEY AND CASE STUDY DER BENEFITS

A review of the surveyed DER installations and the more detailed case studies reveals the variety of benefits that accrue to the owners, energy users, and the utilities. Benefits to other parties are not typically revealed by such survey instruments. Also, note that in today's economic environment, there are no price signals to reveal the value of ancillary services that are available from DER, so that those benefits are also not revealed by the survey.

The broad survey noted each installation owner's reasons for installing DER, and these reasons are a good summary of the owners' perceived benefits. Some owners responded with a single reason, others with four or five. Figure 11 summarizes these reasons. The most common response was to take advantage of cogeneration, which increases the overall energy-use efficiency. Cost reduction was often cited by these same customers. Reliability improvements were nearly as frequent; these included both outage avoidance and power quality considerations. Meeting peak demands was frequently cited as a reason by utility-owned DER installations and was sometimes directly identified as addressing a grid (transmission or distribution) constraint. A significant fraction of the DER were installed in response to regulatory signals; that is, they were designed to avoid peak demand charges or to enable the customer to participate in an interruptible rate structure. Both end-users and utilities cited the avoidance of price spikes as their reason for installing DER.

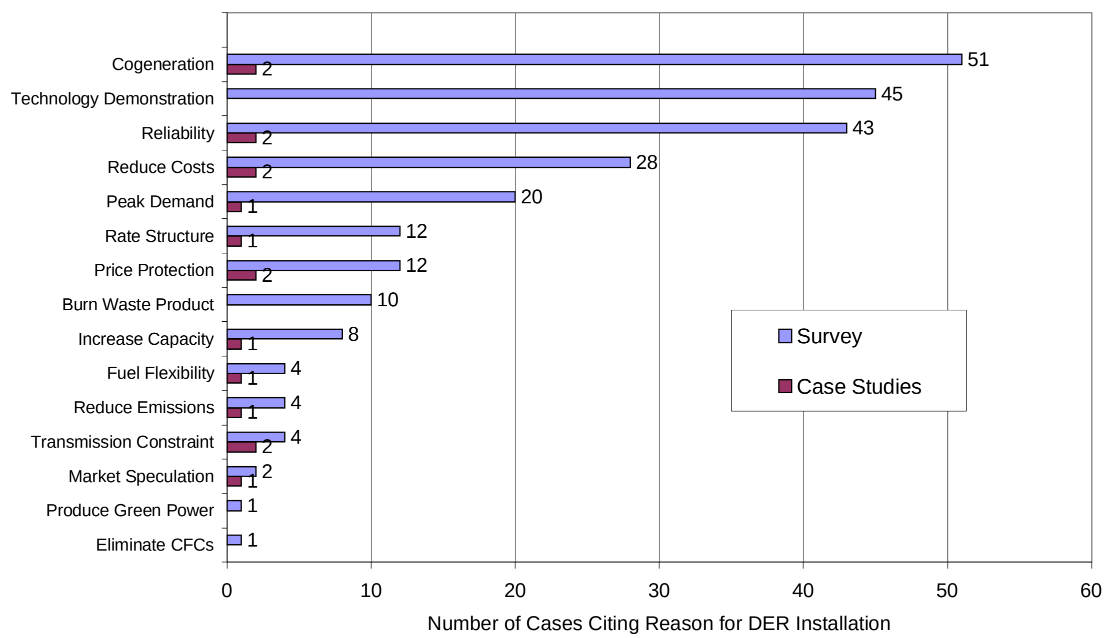

Fig. 11. Reasons cited for installing DER.

A review of the more detailed case studies reveals similar benefits; again cogeneration, reducing costs, increasing reliability, and price protection were leading incentives. One case study was also a clear example of a localized transmission constraint, while two other case studies mentioned such constraints as possible factors.

According to this limited review, a majority of the DER tended to fall into three major categories. Many were installed to meet base load growth or replacement; these typically employ cogeneration and were recognized as reducing overall energy costs. Others were installed to meet peak loads, sometimes by a customer avoiding peak demand charges and sometimes by a utility with a need to serve these less frequently encountered load levels. The selection of DER technology for such peaking applications tended toward those with a lower capital/operating cost ratio in recognition of their relatively low hours of use. The third major category of installations was associated with technology demonstrations. The large proportion of DER demonstrations is closely associated with the rapid pace of change and development in this field as well as with the recognition of DER benefits by both public and private funding organizations.

After the well-understood economic benefits come the more complex issue of reliability benefits. Some of the cases discussed the ability of DER to serve as a back-up power source during an utility power outage. Several discussed the ability of DER to enhance the local power quality, providing a measure of insurance against not only outages but also against voltage sags. This broader area of power quality and ancillary benefits has been more fully explained in Ref. 2, but a rigorous exploration of DER benefits must address them as well. These ancillary benefits include voltage support or stability, VARs, contingency reserves, and black start capability.

Many customers need a higher level of power quality than is presently supplied by their local utility or distribution company. These customers include healthcare, communications, semiconductor manufacturing, some food processing, etc. Voltage sags and interruptions for these customers cause outages which result in a significant economic impact from spoiled products, lost raw materials, lost production time, etc. These customers are aware that they are suffering from a problem with power quality, but the cause of the problem, the extent of the problem, and the solution are not always well known. A few industries have explicitly defined their power quality requirements. Their work offers insight into the impacts of poor power quality on other customers as well and, therefore, may be useful in determining the value of DER power quality improvements.

Semiconductor manufacturers face an extreme cost penalty from voltage sags that interrupt their manufacturing process. The Semiconductors Manufacturer's Institute (SEMI) has developed a power quality requirements curve (see Fig. 12) that gives the minimum voltage vs time that their equipment is expected to ride through. With this curve, they can specify tools such as adjustable speed drives or controllers that are designed to function during the anticipated power quality events. Voltage sag susceptibility information is now available on a range of equipment from computers and microprocessors to relays and solenoid valves. By defining their power quality susceptibility level, the customer could design their DER level to exactly match their power quality needs. Interestingly, in areas with the worst problems with voltage sags, such as at the ends of distribution feeders, ancillary services such as voltage regulation and supplementary reserve are most needed. Further, inverter-based DER (such as microturbines and storage devices) can be designed such that the full dynamic voltage support capability of their active power electronics system is available even when real power is not being produced, i.e., when the DER is turned off and no fuel is being consumed. Appropriately compensating the DER owner is critical for the utility to be able to exploit this capability.

The survey and case studies have identified benefits enjoyed by the customers, and sometimes by the utilities. However, other members of society also gain from the use of DER. When cogeneration increases the overall energy conversion from less than 40% to more than 80%, economic and environmental benefits almost always follow. The economic benefits can include an increase in price stability for other customers, a reduction in the demand for fuel supplies with a corresponding reduction in their cost, a delay in energy price increases associated with a delay in transmission/distribution system

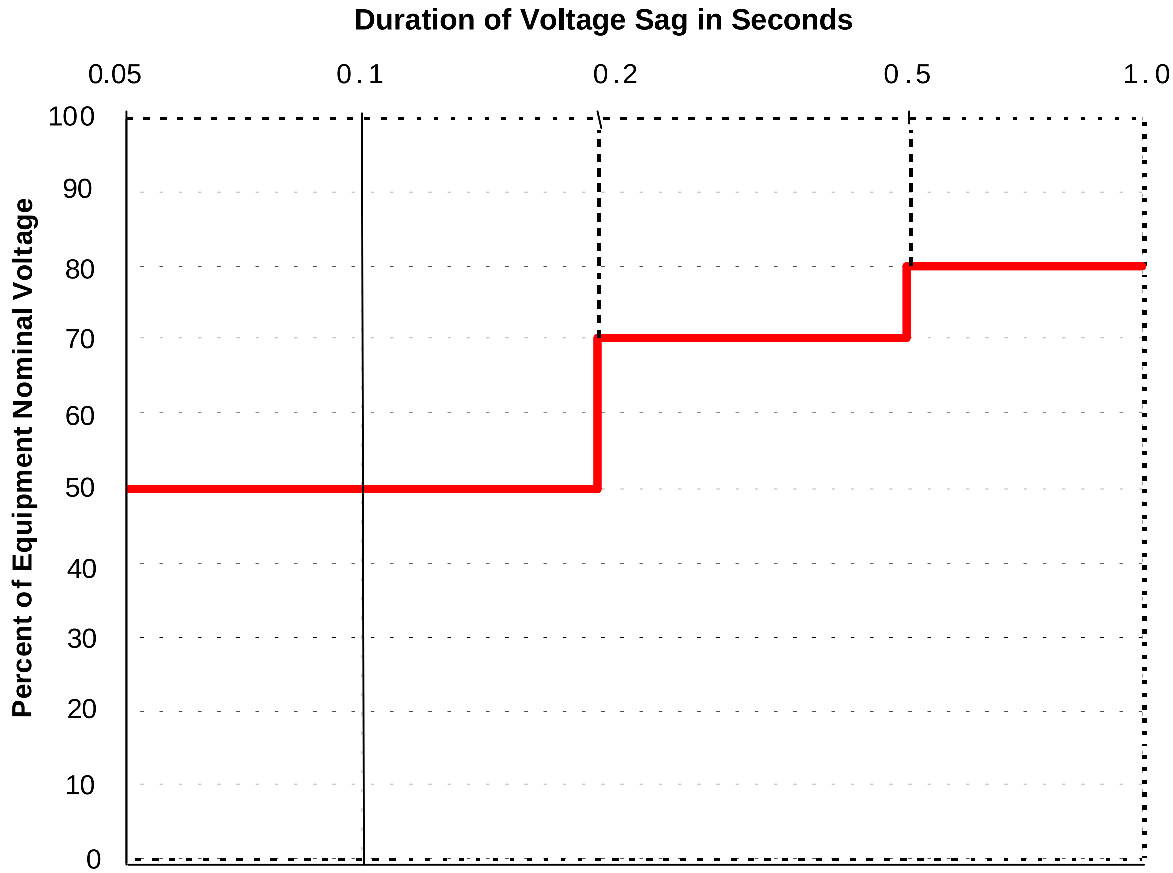

Fig. 12. Semiconductors Manufacturer's Institute power quality requirments.

infrastructures. There can be other, more indirect, economic benefits to society as well. For example, if production waste and other costs decrease, product prices may fall as well.

The environmental benefits are more complex and may not occur in the same geographical location as the DER. For example, if the DER is placed in an urban area, combustion emissions may be reduced in some more remote, less densely populated region but may increase in that local urban environment. In addition to the geographic complexity, the net impact on emissions depends on the DER technologies and on the alternative central station technology. There is also an efficiency gain associated with the production of electricity close to the point of use because that reduces transmission line losses. Some DER technologies, such as cogeneration, are more efficient than central station power generation. The net impact of DER on emissions also depends on the fuel mix used to generate the region's central station power. Figure 13 is a prototypical fuel supply curve. If the DER is gas-fueled and displaces gas, the emissions reduction will depend on the specific technologies and efficiencies involved. If gas-fueled DER displaces coal-fired combustion, there will almost always be a net improvement in the environment, although as described above, that improvement may not be enjoyed in the same location as the DER installation.

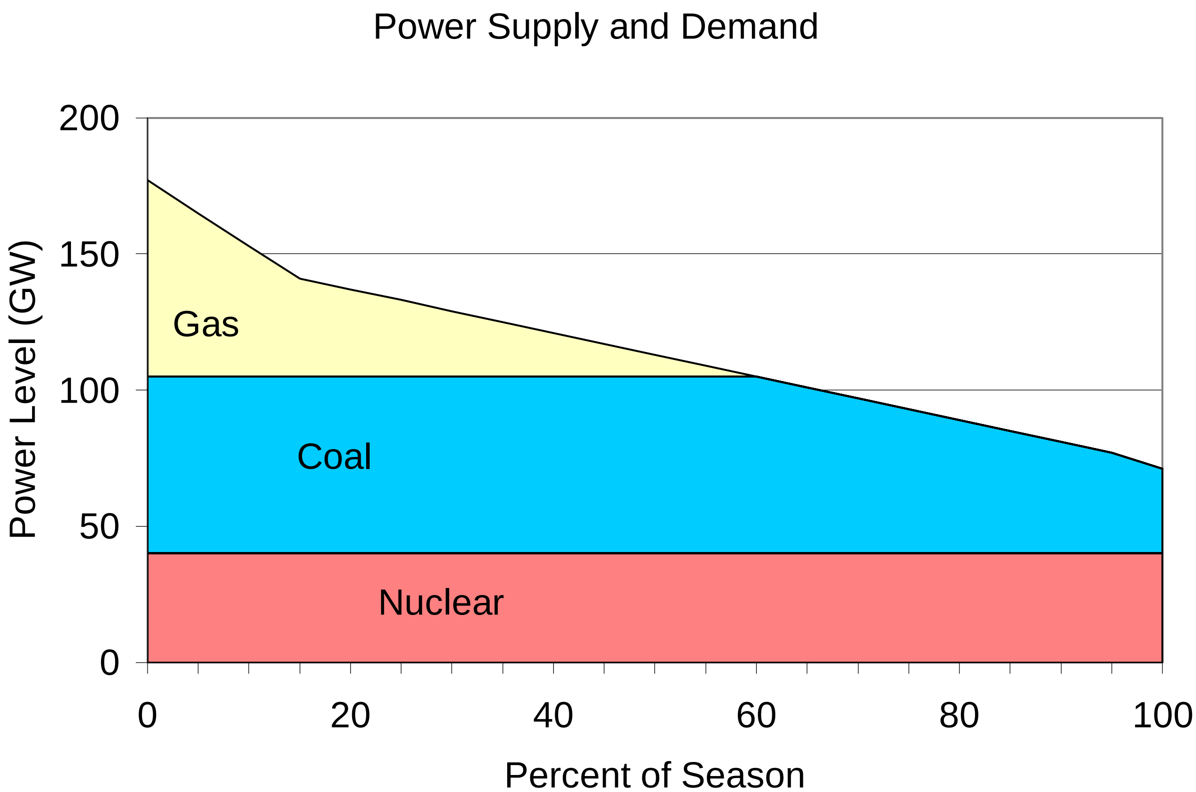

Fig. 13. Prototypical regional electricity production fuel mix curve.

5. ANALYSIS METHODOLOGY

The survey and case studies helped to identify benefits associated with installing and operating DER at various sites. In particular, benefits associated with electric system reliability, power quality, and reduced costs for providing electric power to the site were noted. However, expanding from these anecdotal examples to an overall understanding of the scope and magnitude of DER benefits is not straightforward. Indeed, the efforts described in this report are seen as but the first step in a more comprehensive study of DER benefits.

As in the preceding case studies, the focus of site-specific assessments is typically limited to two parties, the owner/user and the local utility. Rarely are the impacts on other stakeholders, including interconnected distribution utilities, transmission system operators, generating system operators, the local and regional population, local and regional industry and businesses, various levels of government, and the environment considered. The goal of this study is to quantify benefits that accrue broadly across a region, recognizing that DER installations may have local, regional, and national benefits. This complexity will require the development of an assessment methodology that builds upon existing technology and econometric assessment tools.

A literature review (Appendix A) of current, pertinent industry periodicals and articles was conducted to build upon the observations from the site survey and case studies. This review helped identify data sources that will be especially helpful in constructing the assessment methodology.

Despite their advantages, DER installations face a plethora of deployment obstacles. Such barriers have been previously described and documented.[6] The barriers may be technical, business practice, economic, regulatory, or environmental and may add considerable uncertainty to a DER project's viability. Many of these issues are in a state of flux and will, therefore, be examined by defining multiple scenarios. For example, considerable effort has been directed at the DER interconnection standard issue, notably the IEEE P1547, IEEE Std 929, UL 1741, the Public Utility Commission of Texas' Distributed Generation Interconnection Manual, and several other interconnection guides and manuals.[18-21] Because the outcome of these efforts is anything but certain, this benefits methodology will examine several possible interconnection arrangements. Likewise, the Regulatory Assistance Project has closely examined regulatory issues associated with DER. Their work will serve as the foundation for multiple regulatory scenarios within this current study.[4,5,8,9]

Just as this initial evaluation began with specific case studies, the aggregate study will also start with prototypical DER installations. These will be constructed using results from the recently published technical evaluation of the feeder-level performance of DER.[10] Progressing from this prototypical DER installation model to a more global assessment will be accomplished by taking advantage of a number of existing tools.[22-24] These tools have been used in the past to analyze the impact of policies and technologies on air emissions, to study the impact of hydropower facility relicensing, to study the potential reductions from biomass cofiring on a local, regional, and national level, and to study the cost impact of multi-emission regulations vs. emission by emission regulation.[24-26] This set of economic modeling tools were recently expanded to include an assessment of combined heat and power in federal buildings. Although further tool development will be necessary, these modifications provide a solid foundation for this broader assessment of regional distributed energy benefits.

The resulting integrated set of tools will form one macroscopic economic model and will be used to evaluate the effect of distributed energy resources on a regional basis. A detailed recent historical record reflecting the actual prices and generating equipment for a selected region will be used as well. Two cases will be examined initially; first, a base case without access to distributed resources; and second, a case that implements sufficient DER to examine the impact of market structures on the DER's economics. Using these base cases, parametric studies will examine the impact of factors that affect the penetration of distributed resources such as ancillary services markets, need for reliability, or real-time electricity pricing. An early report will be presented describing the analysis methodology and the proposed parametric values.

6. CONCLUSIONS

A brief survey of ~160 existing DER installations and four case studies of specific installations show that DER is now being used in every U.S. state and is providing increasing numbers of owners with high quality and reliable electric power and, with cogeneration, highly efficient energy utilization. Customers are reaping cost savings and gaining improved power quality and reliability. They are also increasing their energy security; a benefit gaining increased attention since the events of September 11.

Interconnected utilities are also benefiting as customer-owned DER helps to mitigate distribution system capacity constraints, provide voltage support, improve the stability of the system, reduce line losses and line congestion, and defer expansion of distribution and transmission facilities. Society benefits from a more secure and stable electric power system and reduced environmental releases.

Most DER assessments are limited to two parties—the owner/user and the local utility. Rarely are the collective benefits (or impacts) on other stakeholders, including interconnected distribution utilities, transmission system operators, generating system operators, other local utility customers, local and regional industry and businesses, various levels of government, and the environment considered, let alone quantified. The objective of the current study is to develop a methodology capable of systematically assessing the combined effects of numerous factors associated with increasing penetrations of DER.

An analysis approach has been outlined in this report to achieve these goals. The analysis will begin with a time-series evaluation of a variety of DER technologies and utility grid situations to provide prototypical values for regional econometric models. Multiple scenarios will be evaluated to consider the wide range of possible regulatory and technical environments. Since costs and benefits are not always evenly distributed, one sector may have relatively higher costs and lower benefits than another. This introduces important issues of cross subsidy, which need to be fully understood when developing market rules. The markets, if properly designed to reflect these externalities, can be powerful tools for prompting desirable investment and operating responses. However, recent experience in California shows that an incomplete understanding of the distributed benefits and costs can lead to an inappropriate market design and disastrous economic consequences. Ultimately, therefore, a more complete picture of the benefits associated with distributed resources will provide invaluable guidance for future policy decisions that impact a host of market rules.

7. REFERENCES

1. U.S. Department of Energy, *Strategic Plan for Distributed Energy Resources*, prepared by the Office of Energy Efficiency and Renewable Energy and Office of Fissil Energy, September 2000.

2. C. R. Hudson, B. J. Kirby, J. D. Kueck, and R. H. Staunton, *Industrial Use of Distributed Generation in Real-Time Energy and Ancillary Service Markets*, ORNL/TM-2001/136, Oak Ridge National Laboratory, Oak Ridge, TN, September 2001.

3. T. Bryson, W. Major, and K. Darrow, *Assessment of On-Site Power Opportunities in the Industrial Sector*, ORNL/TM-2001/169, prepared by Onsite Energy Corporation for Oak Ridge National Laboratory, Oak Ridge, TN, September, 2001.

4. R. Cowart, *Distributed Resources and Electric System Reliability*, Regulatory Assistance Project, Gardiner, ME, September, 2001.

5. D. Moskovitz, *Distributed Resource Distribution Credit Pilot Programs: Revealing the Value to Consumers and Vendors*, Regulatory Assistance Project, Gardiner, ME, September, 2001.

6. B. Alderfer, M. Eldridge, and T. Starrs, *Making Connections: Case Studies of Interconnection Barriers and Their Impacts on Distributed Power Projects*, prepared for the National Renewable Energy Laboratory, Golden, CO, May, 2000.

7. Roger C. Dugan, Thomas E. McDermott, D. T. Rizy, and Stephen J. Steffel, *Interconnecting Single-Phase Backup Generation to the Utility Distribution System*, report prepared by Electrotek, Oak Ridge National Laboratory, and Conectiv.

8. F. Weston, *Accommodating Distributed Resources in Wholesale Markets*, Regulatory Assistance Project, Gardiner, ME, September, 2001.

9. W. Shirley, *Distribution System Cost Methodologies for Distributed Generation*, Regulatory Assistance Project, Gardiner, ME, September, 2001.

10. U. Patel, *DG Power Quality, Protection and Reliability Case Studies Report*, Contract No NAD-1-30605-01, GE Corporate Research and Development for National Renewable Energy Laboratory, September, 2001.

11. Ken Darrow, "CHP: Market Overview," presented at Pacific Northwest CHP Challenge Workshop & Expo, Seattle Washington, Onsite Sycom Energy Corp., March 7, 2000.

12. International District Energy Association, Progress Report to Oak Ridge National Laboratory, 2001.

13. *The Use of DG to Reinforce System Reliability on the Delmarva Peinsula, Study Prepared in Support of Office of Power Technologies, Deliverables Task 6. DER Benefits Study, Task 7. Selected DER Benefits Case Studies*, U.S. Department of Energy, prepared by Electrotek, September 27, 2001.

14. *Distributed Energy Resources*, A Case Study of Vanderbilt University, presented by I. C. Thomasson Associates, Inc., November 2, 2001.

15. Idaho Power Company, I.P.U.C. No. 26, Tariff No. 101.

16. *Interim Report of the U. S. Department of Energy's Power Outage Study Team, Findings from the Summer of 1999*, Paul Carrier, Chairman, Department of Energy, January, 2000.

17. *Meeting Electric Infrastructure Constraints with Distributed Generation, Case Study—Commonwealth Edison Service Territory*, American Gas Association, August 2001.

18. *Draft Standards for Interconnecting Distributed Resources with Electric Power Systems*, IEEE P1547/D08, sponsored by the IEEE Standards Coordinating Committee 21 on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage of the IEEE Standards Association, 2001.

19. John Stevens, *IEEE Std 929-2000—Background, Implications and Requirements*, 2000.

20. *Inverters, Converters, and Controllers for Use in Independent Power Systems*, http://ulstandardsinfonet.ul.com/scopes/1741.html.

21. *Distributed Generation Interconnection Manual*, Public Utility Commission of Texas, prepared by Distributed Utility Associates, and Endecon Engineering, March 15, 2001.

22. S. W. Hadley, *ORFIN: An Electric Utility Financial and Production Simulator*, ORNL/CON-430, Oak Ridge National Laboratory, Oak Ridge, TN, March 1996.

23. S. W. Hadley and E. Hirst, *ORCED: A Model to Simulate the Operations and Costs of Bulk-Power Markets*, ORNL/CON-464, Oak Ridge National Laboratory, Oak Ridge, TN, June 1998.

24. Energy Information Administration, Office of Integrated Analysis and Forecasting, *National Energy Modeling System: An Overview 2000*, Department of Energy, Energy Information Administration, March 2000.

25. S. W. Hadley, *The Impact of Carbon Taxes or Allowances on the Electric Generation Market in the Ohio and ECAR Region*, ORNL/CON-463, Oak Ridge National Laboratory, Oak Ridge, TN, July 1998.

26. M. J. Sale and S. W. Hadley, *Estimating Hydropower's Contribution to the Control of Greenhouse Gas Emissions*, Waterpower XII Conference, Salt Lake City, UT, July 9–11, 2001.

APPENDIX A—BIBLIOGRAPHY

General

1. DOE Strategic Plan for Distributed Energy Resources, September 2000.

2. *Distributed Resources Web (www.disgen.com)*, in EPRI Solutions Web site.

3. *Distributed Generation—Securing America's Future with Reliable, Flexible Power*, prepared for the U.S. Department of Energy, Office of Fossil Energy, Federal Energy Technology Center.

4. *National CHP Roadmap—Doubling Combined Heat and Power Capacity in the United States by 2010*, prepared by the United States combined Heat & Power Association in cooperation with U.S. Department of Energy, U.S. Environmental Protection Agency, March 2001.

5. *Strategic Plan for Distributed Energy Resources*, prepared by Office of Energy Efficiency and Renewable Energy, Office of Fossil Energy, U.S. Department of Energy, September 2000.

6. Thomas E. Hoff and Christy Herig, *The Benefits of Distributed Resources to Local Governments: An Introduction*, a presentation in Chicago, IL, September 21, 2000.

7. Thomas E. Hoff, *The Benefits of Distributed Resources to Local Governments: An Introduction*, prepared for Christy Herig, National Renewable Energy Laboratory, September 12, 2000 (Draft).

8. Marc W. Goldsmith, *Distributed Generation—The Next Wave of the Technology-Enabled Revolution*, presentation to the Edison Electric Institute, June 2001.

9. "Energy Infrastructure: Electricity Transmission Lines," from *Energy Facts—An Educational Series Designed for Policymakers*, Alliance for Energy and Economic Growth.

10. "Bibliography List from "E3 Publications," from http://www.ethree.com/Consulting/e3pubs.htm .

11. "Utility Case Study: T*D Siting in Nashville," in *Electrotek Concepts*.

12. "Web-Based Operational Solutions for Energy and Utility Companies," from website http://www.livedata.com/default.htm.

13. "Distributed Power Program" website, http://www.eren.doe.gov/distributedpower/.

14. Karl Stahlkopf and Wade Malcolm, "Distribution System Technology for the 21st Century," in *The Electricity Journal*, pp. 49–57 (May 1998).

15. Thomas Ackermann, Göran Andersson, and Lennart Söder, "Distributed Generation: A Definition," in *Electric Power Systems Research*, **57**, pp. 195–204 (2001).

16. Douglas J. Smith, "Distributed Generation: The Power to Choose," in *Power Engineering*, **105(3)**, pp. 32–36 (March 2001).

17. *Distributed Energy: Towards a 21st Century Infrastructure*, A Report of The Consumer Energy Council of America Distributed Energy Domestic Policy Forum, July 2001.

18. Brendan Kirby and Eric Hirst "Maintaining Transmission Adequacy in the Future," in *The Electricity Journal*, pp. 62–72 (November 1999).

19. Rod Taylor, "Let's Not Come Down Too Hard on Grids," in "Letters to the Editor" in *The Electricity Journal*, pp. 2–3 (October 2000).

20. "Distributed Generation: An Action Plan for Co-ops," in *Management Quarterly*, **40(2)**, pp. 20*ff* (Summer 1999).

21. "The Distributed Future—Technological Advances and Deregulation Offer More and More Opportunities to Put Generation Closer to the Load," in *Electric Perspectives*, **23(3)**, pp. 20*ff* (May/June 1998).

22. R. Brent Alderfer, M. Monika Eldridge, and Thomas J. Starrs, *Making Connections—Case Studies of Interconnection Barriers and Their Impact on Distributed Power Projects*, NREL/SR-200-28053, National Renewable Energy Laboratory, May 2000.

23. Jay Morrison, *White Paper on Distributed Generation*, prepared for the National Rural Electric Cooperative Association.

24. *Distributed Utility Planning: An Introduction to Concepts and Issues*, from Web site http://www.state.vt.us/psd/ee/ee-DUP.htm .

25. *The Role of Distributed Generation in Competitive Energy Markets*, from the "Distributed Generation Forum," March 1999.

26. Eric Hirst, *The California Electricity Crisis—Lessons for Other States*, prepared for Edison Electric Institute, July 2001.

27. "Distributed Generation Report 07/16/01–07/29/01," in *Energy Info Source: Your World of Energy* (2001).

28. "MMW1.0: Not Only for Substations," in *Power Delivery News*, June 1999.

29. "Advice to Utilities: Embrace DG," from *Distributed Power News*, June 2001.

30. Steven P. Lindenberg, *Distributed Generation: An Action Plan for Co-ops*.

31. Thomas Ackermann, Göran Andersoon, and Lennart Söder, "Distributed Generation: A Definition," in *Electric Power Systems Research*, **57**, pp. 195–204 (2001).

Reliability and Technical

32. Brendan Kirby and Eric Hirst, *Bulk-Power Reliability and Commercial Implications of Distributed Resources*, February 5, 2000.

33. *Least-Cost Paths to Reliability: Ten Questions for Policy Makers*, from web site http://www.rapmaine.org/Reliability.htm.

34. *Reliability Assessment 1997–2006: The Reliability of Bulk Electric Systems in North America*, prepared for the North American Electric Reliability Council, October 1997.

35. *Findings and Recommendations to Enhance Reliability from the Summer of 1999* (Final Report), a Report of the U.S. Department of Energy's Power Outage Study Team, March 2000.

36. Benjamin F. Hobbs, "Optimization Methods for Electric Utility Resource Planning," in *European Journal of Operational Research*, **83**, pp. 1–20 (1995).

37. Ching-Tzong Su and Guor-Rurng Lii, "Reliability Planning for Composite Electric Power Systems," in *Electric Power Systems Research*, **51,** pp. 23–31 (1999).

38. Graham W. Ault and James R. McDonald, "Planning for Distributed Generation Within Distribution Networks in Restructured Electricity Markets," in *IEEE Power Engineering Review*, pp. 52–54 (February 2000).

39. A. Sundaram, *Power Quality Impacts of Distributed Generation. Guidelines—Final Report*, EPRI, December 2000.

40. B. Banerjee, *Capacity Planning, Power Quality, Reliability, and Availability for Internet Facilities. Volume 1: Digital Society Evolution, Issues Facing Stakeholders, and E-Commerce Market Segments—Final Report*, EPRI, December 2000.

41. B. Banerjee, *Capacity Planning, Power Quality, Reliability, and Availability for Internet Facilities. Volume 2: Technical Considerations—Final Report*, EPRI, December 2000.

42. L. Goel, "Power System Reliability Cost/Benefit Assessment and Application in Perspective," in *Computers & Electrical Engineering*, **24**, pp. 315–324 (1998).

43. J. O. Kim, S. W. Nam, S. K. Park, and C. Singh, "Dispersed Generation Planning Using Improved Hereford Ranch Algorithm," in *Electric Power Systems Research*, **47**, pp. 47–55 (1998).

44. Marija D. Ilić, José R. Arce, Yong T. Yoon, and Elena M. Fumagalli, "Assessing Reliability as the Electric Power Industry Restructures," in *The Electricity Journal*, pp. 55–67 (March 2001).

45. *Distributed Generation: System Interfaces*, An Arthur D. Little White Paper, 1999.

46. Brendan Kirby and John Kueck, *Review of the Structure of Bulk Power Markets Grid of the Future White Paper*, ORNL/TM-2000/41, January 2000.

47. Rich Cowart and Cheryl Harrington, *Distributed Resources and Electric System Reliability* (Review Draft), February 2001.

48. Richard H. Cowart et al., *Efficient Reliability: The Critical Role of Demand-Side Resources in Power Systems and Markets*, prepared for The National Association of Regulatory Utility Commissioners, June 2001.

49. L. Goel, "Power System Reliability Cost/Benefit Assessment and Application in Perspective," in *Computers & Electrical Engineering*, **24**, pp. 315–324 (1998).

50. "Distributed Generation Reliability Metrics," web site http://www.gri.org/pub/solutions/dg/rel_metrics.html .

51. Will McNamara, "Nstar Takes Steps to Increase Reliability," in *Energy Info Source: Industry Commentary: Issue Alerts*.

52. *Power Delivery News*, EPRI Newsletter, October 2000.

53. "Consortium for Electric Infrastructure to Support a Digital Society," in *Power Delivery News*, March 2001.

54. *Power Delivery News*, EPRI Newsletter, July 1998.

Economics and Regulatory

55. "EPRI Planning Tools Help PSEG Tackle Growth: Distribution Expansion Strategies, Hudson River Waterfront," from EPRI Area Investment Strategy Model.

56. Thomas E. Hoff (Stanford University and Pacific Energy Group) and Christy Herig (National Renewable Energy Laboratory), "Managing Risk Using Renewable Energy Technologies," to be published in *The Virtual Utlity: Accounting, Technology & Competitive Aspects of the Emerging Industry*, Shimon Awerbuch and Alistair Preston (eds.), Kluwer Academic Publishers, Norwell, MA.

57. Fred Gordon (Pacific Energy Associates, Inc.), Joe Chaisson (Joe Chaisson and Associates), and Dave Andrus (Economic and Engineering Associates), *Helping Distributed Resources Happen: A Blueprint for Regulators, Advocates, and Distribution Companies*, Final Report, published for Eric Heitz of The Energy Foundation.

58. B. Kirby and N. Lenssen, *Shifting the Balance of Power: Grid Interconnection of Distributed Generation*, E Source, The Distributed Energy Series, Boulder, Colorado, October 1999.

59. R. Staunton, J Kueck, B. Kirby, and J. Eto, "Demand Response: An Overview of Enabling Technologies," *Public Utilities Fortnightly*, November 2001.

60. J. D. Kueck, B. J. Kirby, J. Eto, R. H. Staunton, C. Marnay, C. A. Martinez, and C. Goldman, *Load as a Reliability Resource in Restructured Electricity Markets*, ORNL/TM-2001/97, Oak Ridge National Laboratory, Oak Ridge TN, June 2001.

61. E. Hirst and B. Kirby, *Metering, Communications and Computing for Price-Responsive Demand Programs*, April 2001.

62. B. Kirby and E. Hirst, *Using Five-Minute Data to Allocate Load-Following and Regulation Requirements Among Individual Customers*, ORNL/TM-2001-13, Oak Ridge National Laboratory, Oak Ridge TN, January 2001.

63. E. Hirst and B. Kirby, *Retail-Load Participation in Competitive Wholesale Electricity Markets*, Edison Electric Institute, Washington, DC, and Project for Sustainable FERC Energy Policy, Alexandria, VA, December 2000.

64. B. Kirby and J. Kueck, *How Buildings Can Prosper by Interacting with Restructured Electricity Markets*, ACEEE, August 2000.

65. B. Kirby and E. Hirst, *Load as a Resource in Providing Ancillary Services*, American Power Conference, Chicago, Illinois, April 1999.

66. B. Kirby, “Restructured Electricity Markets Offer Increased Complexities and Opportunities for Cogeneration,” *Cogeneration and Competitive Power Journal* (2001).

67. B. Kirby, *Restructured Electricity Markets Offer Increased Complexity and Increased Opportunities*, Association of Energy Engineers, Globalcon, April 2000.

68. E. Hirst and B. Kirby, *Bulk-Power Basics: Reliability and Commerce*, The Regulatory Assistance Project, Gerdiner, ME, March 2000.

69. E. Hirst, B. Kirby and S. Hadley, *Generation and Transmission Adequacy in a Restructuring U.S. Electricity Industry,* Edison Electric Institute, Washington, DC, June 1999.

70. E. Hirst and B. Kirby, *Unbundling Generation and Transmission Services for Competitive Electricity Markets*, ORNL/CON-454, Oak Ridge National Laboratory, Oak Ridge TN, January 1998.

71. E. Hirst and B. Kirby, “Simulating the Operation of Markets for Bulk-Power Ancillary Services,” *The Energy Journal*, **19(3)** (1998).

72. E. Hirst and B. Kirby, “Key Transmission Planning Issues,” *The Electricity Journal*, October 2001.

73. E. Hirst and B. Kirby, “Transmission Planning: Weighing Effects on Congestion Costs,” *Public Utility Fortnightly*, July 2001.

74. E. Hirst and B. Kirby, *Transmission Planning for a Restructuring U.S. Electricity Industry*, Edison Electric Institute, Washington, DC, June 2001.

75. B. Kirby and E. Hirst, “Real-Time Performance Metrics for Generators Providing the Regulation Ancillary Service,” *The Electricity Journal*, April 2001.

76. B. Hirst and B. Kirby, *Measuring Generator Performance in Providing Regulation and Load-Following Ancillary Services*, ORNL/TM-2000-383, Oak Ridge National Laboratory, Oak Ridge TN, January 2001.

77. B. Kirby and E. Hirst, “Generator Response to Intrahour Load Fluctuations,” *IEEE Transactions on Power Systems*, Vol 13 No.4, PE-627-PWRS-0-12-1997 (November 1998).

78. E. Hirst and B. Kirby, *Ancillary-Service Details: Regulation, Load Following, and Generator Response*, ORNL/CON-433, Oak Ridge National Laboratory, Oak Ridge, TN, September 1996.

79. J. Cadogan, M. Milligan, Y. Wan, and B. Kirby, *Short Term Output Variations in Wind Farms — Implications for Ancillary Services in the United States*, October 2000.

80. B. Ernst, Y. Wan and B. Kirby, “Short-Term Power Fluctuation of Wind Turbines: Looking at Data from the German 250 MW Measurement Program from the Ancillary Services Viewpoint,” American Wind Energy Association Windpower ‘99 Conference, Washington, DC, June 1999.

81. B. Kirby, E. Hirst, B. Parsons, K. Porter, and J. Codagan, *Electric Industry Restructuring, Ancillary Services, and the Potential Impact on Wind*, American Wind Energy Association, June 1997.

82. B. Kirby and E. Hirst, *Pricing Ancillary Services So Customers Pay for What They Use*, EPRI, July 2000.

83. E. Hirst and B. Kirby, "Time-Averaging Period For the Regulation Ancillary Service," *IEEE Power Engineering Review*, July 2000.

84. B. Kirby and E. Hirst, *Customer-Specific Metrics for The Regulation and Load-Following Ancillary Services*, ORNL/CON-474, Oak Ridge National Laboratory, Oak Ridge TN, January 2000.

85. E. Hirst and B. Kirby, "Ancillary Services: A Call for Fair Prices," *Public Utilities Fortnightly*, January 2000.

86. B. Kirby and E. Hirst, "New Blackstart Standards Needed for Competitive Markets," *IEEE Power Engineering Review*, Vol. 19, No. 2, pp9, February 1999.

87. E. Hirst and B. Kirby, *Creating Markets for Ancillary Services, Pricing Energy in a Competitive Market*, EPRI, June 1998.

88. B. Kirby and E. Hirst, *Characteristics of Concern in Supplying, Consuming, and Measuring Ancillary Services, The Future of Power Delivery in the 21st Century*, The Electric Power Research Institute, Palo Alto, CA, May 1998.

89. B. Hirst and B. Kirby, Ancillary Services: "The Neglected Feature of Bulk-Power Markets," *The Electricity Journal*, April 1998.

90. B. Kirby and E. Hirst, *Ancillary-Service Details: Voltage Control*, ORNL/CON-453, Oak Ridge National Laboratory, Oak Ridge TN, December 1997.

91. E. Hirst and B. Kirby, *Ancillary-Service Details: Operating Reserves*, ORNL/CON-452, Oak Ridge National Laboratory, Oak Ridge TN, November 1997.

92. E. Hirst and B. Kirb, *Creating Competitive Markets for Ancillary Services*, ORNL/CON-448, Oak Ridge National Laboratory, Oak Ridge TN, October 1997.

93. E. Hirst and B. Kirby, *Ancillary-Service Details: Dynamic Scheduling*, ORNL/CON-438, Oak Ridge National Laboratory, Oak Ridge TN, January 1997.

94. B. Kirby and E. Hirst, *Ancillary-Services Costs for Twelve U.S. Electric Utilities*, ORNL/CON-427, Oak Ridge National Laboratory, Oak Ridge, TN, March 1996.

95. E. Hirst and B. Kirby, *Electric-Power Ancillary Services*, ORNL/CON-426, Oak Ridge National Laboratory, Oak Ridge, TN, February 1996.

96. "Executive Summary," from *Conference Proceedings of the Distributed Generation Roundtable,* April 25–26, 1996.

97. Thomas E. Hoff, Howard J. Wenger, and Brian K. Farmer, *Distributed Generation: An Alternative to Electric Utility Investments in System Capacity*, from web site http://www.clean-power.com/research/distributedgeneration/dg.pdf.

98. "Small Is Profitable: Why Our Bigger-is-Better Electricity System's Days are Numbered," from Web site http://www.rmi.org/sitepages/pid303.php.

99. Thomas J. Starrs and Howard J. Wenger, *Policies to Support A Distributed Energy System*, REPP Special Report.

100. Nick Lenssen, "How Will Distributed Generation be Deployed?" from Web site http://www.localpower.org/article.html .

101. "Working with Regulators to Reveal the Value of Distributed Resources," The Regulatory Assistance Project from web site http://www.eren.doe.gov/distributedpower/review2001pres/rap_q2.ppt.

102. Robert J. Camfield and Anthony G. Schuster, "Pricing Transmission Services Efficiently," in *The Electricity Journal*, pp. 13–32 (November 2000).

103. Douglas J. Smith, "Cogeneration, Distributed Generation and Peak Shaving Drive the Market for Small Gas Turbines," in *Power Engineering*, **104(10)**, pp. 70–74 (October 2000).

104. "Marginal Capacity Costs of Electricity Distribution and Demand for Distributed Generation[A]," in *Energy Journal*, **16(2)**, pp. 111ff (1995).

105. "Changing the Rules for Independent Power Producers," in *International Power Generation*, 21(5), pp. 53ff (July 1998).

106. Michael Hsu, "An Introduction to the Pricing of Electric Power Transmission," in *Utilities Policy*, **6(3)**, pp. 257–270 (1997).

107. B. W. Ang, J. P. Huang, and K. L. Poh, "Break-Even Price of Distributed Generation Under Uncertainty," in *Energy*, **24**, pp. 579–589 (1999).

108. David E. Dismukes and Andrew N. Kleit, "Cogeneration and Electric Power Industry Restructuring," in *Resource and Energy Economics*, **21**, pp. 153–166 (1999).

109. Nainish K. Gupta and Herbert G. Thompson, Jr., "Buying Wires: The Market Value of Transmission Assets," in *The Electricity Journal*, pp. 50–54 (April 2000).

110. Robert A. Laurie, "Distributed Generation: Reaching the Market Just in Time," Guest Editorial in *The Electricity Journal*, pp. 87–94 (March 2001).

111. "Distributed Generation: Policy Framework for Regulators," An Arthur D. Little White Paper, 1999.

112. "Distributed Generation: Understanding the Economics," An Arthur D. Little White Paper, 1999.

113. David Moskovitz, "Profits and Progress Through Distributed Resources," in *The Regulatory Assistance Project*, February 2000.

114. "Distributed Resources and Distribution Company Profitability (Draft), in *The Regulatory Assistance Project*, April 28, 1999.

115. Wayne Shirley, Richard Cowart, Rich Sedano, Frederick W. Weston, Cheryl Harrington, and David Moskovitz, "Distribution System Cost Methodologies for Distributed Generation," prepared for The National Renewable Energy Laboratory, The Regulatory Assistance Project, July 31, 2001.

116. Thomas E. Hoff, "Using Distributed Resources to Manage Risks Caused by Demand Uncertainty," from web site http://clean-power.com/research/distributedgeneration/udrmr.pdf.

117. Thomas E. Hoff, "Identifying Distributed Generation and Demand Side Management Investment Opportunities," from web site http://clean-power.com/research/distributedgeneration/idg.pdf.

118. "Performance Based Regulation—A Policy Option for A Changing World," from web site http://www.rapmaine.org/pbreg.html.

119. Resource Dynamics Corporation, "Economics of Distributed Generation: T&D Applications," presented at the AEIC–COEPA 1999 Meeting, Santa Fe, NM, September 28, 1999.

Standards

120. "Working Safely with Photovoltaic Systems", prepared by Daystar, Inc., Energy Engineering.

121. Chris Larsen, Bill Brooks, Tom Starrs, "Connecting to the Grid. A Guide to PV Interconnection Issues", Third Edition, prepared for the Interstate Renewable Energy Council's PV4You Interconnection Project, 2000.

122. "Inverters, Converters, and Controllers for Use in Independent Power Systems," UL-1741, Underwriters Laboratories, Inc., January 17, 2001.

123. IEEE P1547/D07—Draft Standard for Interconnecting Distributed Resources with Electric Power Systems, IEEE Standards Coordinating Committee 21 on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage of the IEEE Standards Association, 2001.

124. Distributed Utility Associates and Endecon Engineering, *Distributed Generation Interconnection Manual*, prepared for the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, March 15, 2001.

125. *IEEE Recommended Practice for Utility Interface of Photovoltaic (PV) Systems*, Institute of Electrical and Electronics Engineers, Inc., 2000.

126. John Stevens, *The Interconnection Issues of Utility-Intertied Photovoltaic Systems*, SAND 87-3146, Sandia National Laboratories, June 1997.

Environmental

127. Peter S. Glaser, "Green Power Marketing Claims: A Free Ride on Conventional Power?" in *The Electricity Journal*, pp. 32–40 (July 1999).

128. Edward M. Meyer and Mannshya Grace Hu, “Clean Distributed Generation: Policy Options to Promote Clean Air and Reliability,” in *The Electricity Journal*, pp. 89–98 (January/February 2001).

129. Nathanael Greene and Roel Hammerschlag, “Small and Clean is Beautiful: Exploring the Emissions of Distributed Generation and Pollution Prevention Policies,” in *The Electricity Journal*, pp. 50–60 (June 2000).

130. Sheryl Carter, “Emissions from Distributed Generation,” presented to the California Energy Commission Siting Committee Workshop, Evaluating Distributed Generation CEQA and Permit Streamlining, April 20, 2000.

Miscellaneous Reports

131. *Distributed Generation Monitor*, Volume 1, Issue 4 (June/July 2001).

132. *Distributed Generation Monitor*, Volume 1, Issue 3 (April/May 2001).

133. *Distributed Generation Monitor*, Volume 1, Issue 2 (February/March 2001).

134. “Reliability of Natural Gas Power Generation Systems,” in *Natural Gas Power Generation Solutions.*

135. Electricity Generation: “A Key Element of Reliability,” from the Edison Electric Institute.

136. A. B. Poole, “Distribution Efficiency of Electrical Power,” presentation, March 11, 1998.

137. Steven Nadel, Fred Gordon, and Chris Neme, “Using Targeted Energy Efficiency Programs to Reduce Peak Electrical Demand and Address Electric System Reliability Problems,” an ACEEE publication, November 2000.

138. Chi-Keung Woo, “What Went Wrong in California’s Electricity Market?” in *Energy*, **26**, pp. 747–758 (2001).

139. Syska & Hennessy, *Task C2 Report for Evaluate Building Heating and Cooling Systems*, DG System Integration and Reliability Impacts on Telecommunication Facilities Project, submitted to Oak Ridge National Laboratory, reference Subcontract 4000006128, ZGP-01-000.

140. Syska & Hennessy, *Task C5 Report for Schematic Design*, DG System Integration and Reliability Impacts on Telecommunication Facilities Project, submitted to Oak Ridge National Laboratory, reference Subcontract 4000006128, ZGP-01-000.

141. Syska & Hennessy, *Task C3 Report to Evaluate Heat Recovery Options*, DG System Integration and Reliability Impacts on Telecommunication Facilities Project, submitted to Oak Ridge National Laboratory, reference Subcontract 4000006128, ZGP-01-000.

142. Syska & Hennessy, *Task C1 Report for Analysis of Existing Electrical System*, DG System Integration and Reliability Impacts on Telecommunication Facilities Project, submitted to Oak Ridge National Laboratory, reference Subcontract 4000006128, ZGP-01-000.

143. *Distributed Energy Resources Annual Operating Plan Fiscal Year 2001* (Draft), U.S. Department of Energy, Office of Power Technologies, Office of Energy Efficiency and Renewable Energy, October 24, 2000.

144. "Crisis in California: Part 1 What Really Happened, and Why," in *Management Quarterly*, **42(2),** pp. 44ff (Summer 2001).

145. G. A. Kern, R. H. Bonn, J. Ginn, and S. Gonzalez, "Results of Sandia National Laboratories Grid-Tied Inverter Testing," presented at the 2nd World Conference and Exhibition on Photovoltaic Solar Energy Conversion, Vienna, Austria, July 6–10, 1998.

146. Steve Hester, "IEEE 929-2000 Recommended Practice for Utility Interface of Photovoltaic (PV) Systems," a presentation.

147. Chi-Keung Woo, Ira Horowitz, and Khoa Hoang, "Cross Hedging and Forward-Contract Pricing of Electricity," in *Energy Economics*, **23**, pp. 1–15 (2001).

148. "Waste Heat Absorption Chillers," in Absorption Cooling Web site http://www.mechanicalsystems.com/absorpti.htm .

149. "The Alliance and Its Objectives," in the Alliance for Energy & Economic Growth, http://www.yourenergyfuture.org/aboutus.cfm.

Addendum 1 follows, added March 2002

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March 27, 2002

To: Distribution
From: Therese K. Stovall
Subject: Additional DER Survey Data Analysis

Per a request from David Bassett, an additional analysis of the survey data reported by Electrotek as a part of the Phase I DER Benefits Study was completed and is reported here. If you have any questions, please let me know.

A survey was previously described in which the owners' reasons for installing Distributed Energy Resources were reported for 162 installations in the U.S.(see ORNL/TM-2001/290) However, among these 162 installations, 49 were demonstration units, usually fuel cells or microturbines. Another 33 installations contained incomplete information about either the type or size of the DG installation. This update shows the distribution of the survey results for the data set without these demonstration units, and the data set with both the demonstration and incomplete cases removed.

Two fuel cell cases remain in this data set. They are both situations with extreme environmental sensitivities, one in New York's Central Park and the other on an Indian Reservation. In both cases, remote (relative to the local grid) power needs with minimal environmental impact drove the technology selection. The five microturbine cases that remain in this data set are split almost evenly between utilities burning waste gas, and customers taking advantage of cogeneration economics and rate structure incentives. The remaining PV and wind sites represent situations remote from power lines (a cattle ranch) and utilities generating "green" power to meet market demands.

For the most restrictive data set, that with both the demonstration and incomplete cases removed, economic reasons were cited by 45%, environmental reasons by 16%, and meeting peak demands by 39%. Half the installations were owned by 'power' companies, either utilities, or third party energy supply companies. These power company installations represent about 2/3 of the installed capacity reported in this survey. A total of 32 installations cited reliability concerns as a reason for installation, and for 11 of these 32 installations, reliability was the ***only*** reason given. More than half of the customers are installing DER to reduce their "uncertainty" factor, defined here by a combination of reasons including reliability, price protection, and fuel flexibility; these add up to 43 out of 80 cases. Figures 1-7 summarize the results for this data set.

Cogeneration was the dominant reason given for installing DER in this survey. An examination of which DER technologies are used with cogeneration is shown in Fig. 7. It is interesting to note that the gas-fired reciprocating engines are just as likely to provide cogeneration as the combustion turbines. These gas-fired reciprocating engines tended to be larger in capacity and to be owned by customers, compared to the diesel-fired reciprocating engines, which tended to be smaller in capacity and to be leased by utilities. The diesel-fired reciprocating engines, as well as the PV and wind installations, were least likely to employ cogeneration.

For the data set without demonstration cases, but which still contains those cases for which only partial information is available, please see Figures 8-13.

There are also several situations reported in the survey which don't translate well to graphs and charts. One utility is using DG to serve a short-term mining load. A communications company is placing DG at multiple sites to both provide back-up power and to serve as their main power source until the utility grid reaches their more remote sites. A chain of car washes and gas stations has installed small DG units and taken their loads off the grid completely. Another utility is contracting with existing back-up DER owners for control of their units to meet peak demands. Eleven universities are included in the data, all but one of which use cogeneration to meet their campus heating and/or cooling loads.

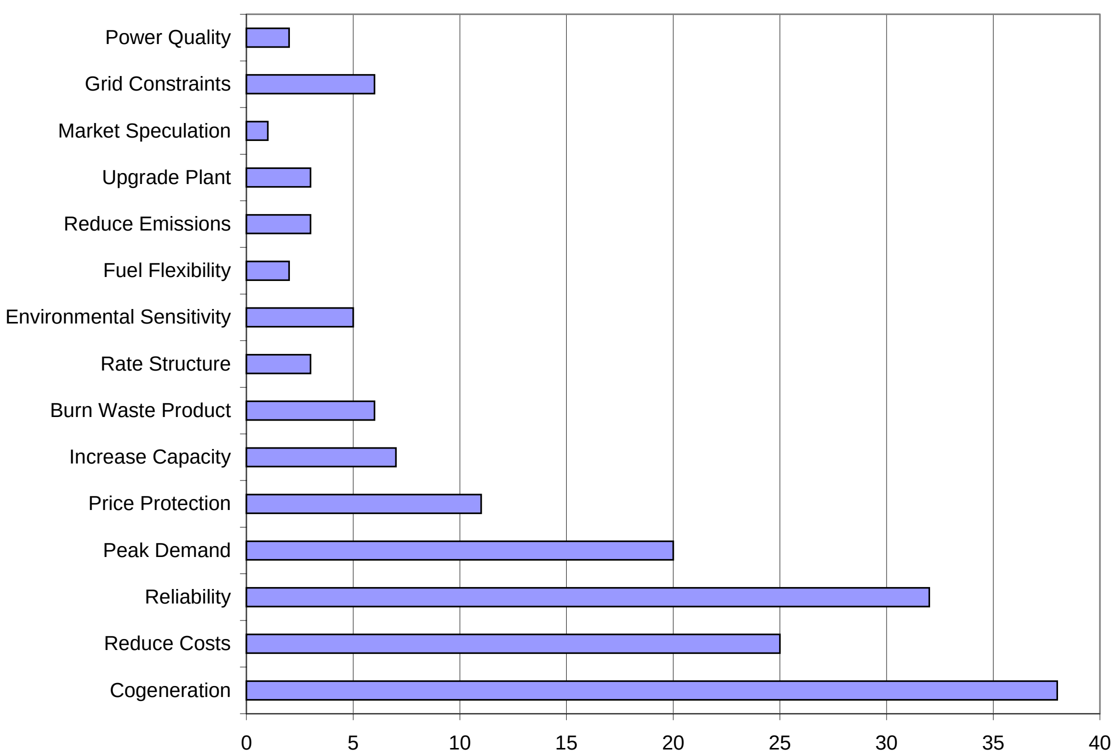

Figure 1 Number of cases citing each reason for their DG installation, demonstration and incomplete cases deleted.

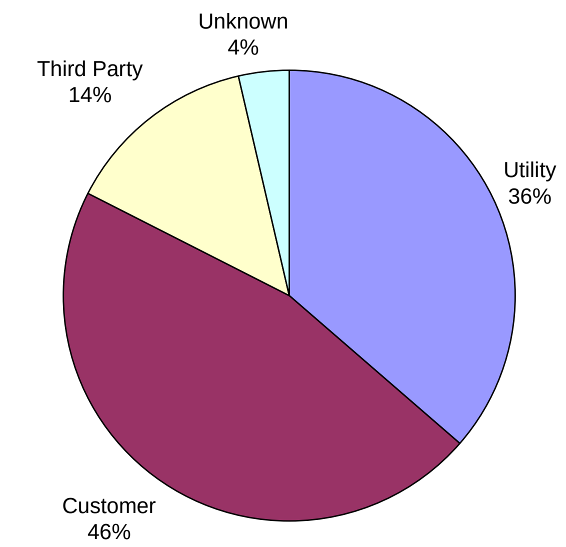

Figure 2 Type of ownership by number of installations, demonstration and incomplete cases deleted.

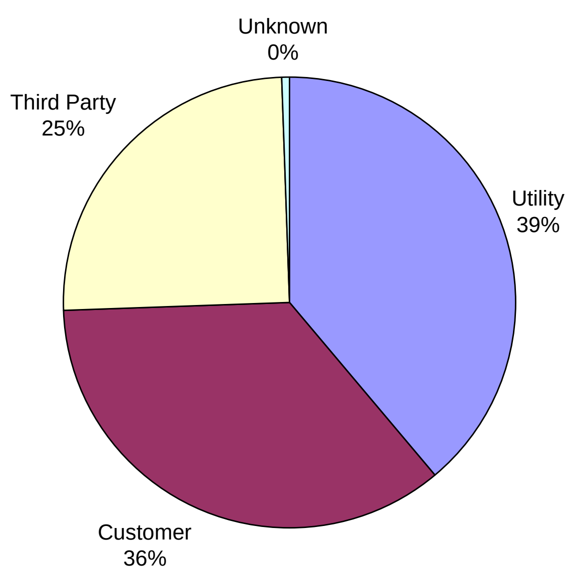

Figure 3 Type of ownership by installed capacity, demonstration and incomplete cases deleted.

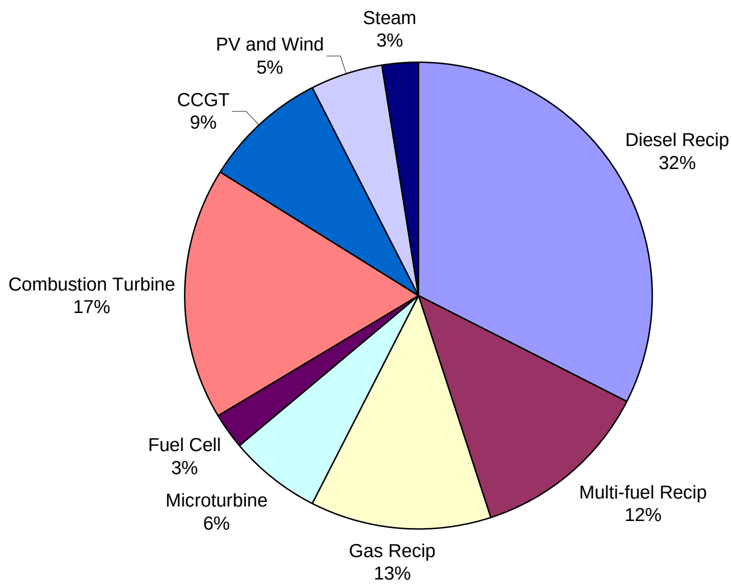

Figure 4 DER technology breakdown by the number of installations, demonstration and incomplete cases deleted.

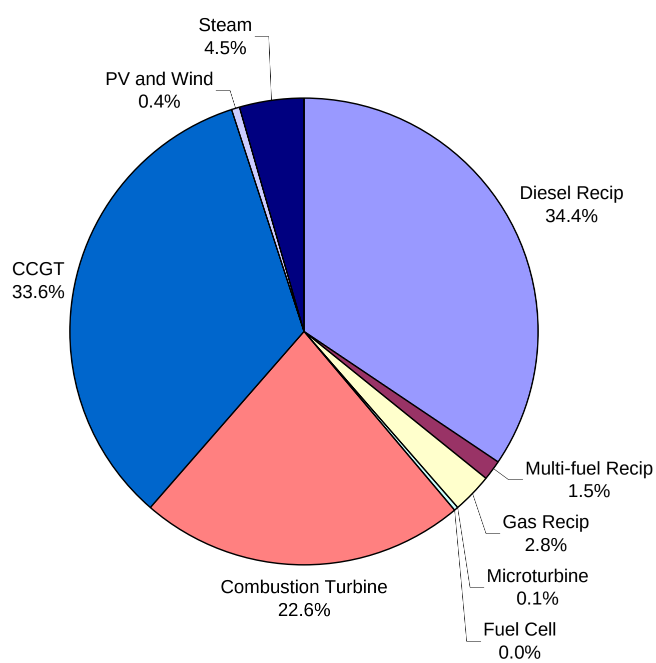

Figure 5 Distribution of DER technologies by installed capacity, demonstration and incomplete cases deleted.

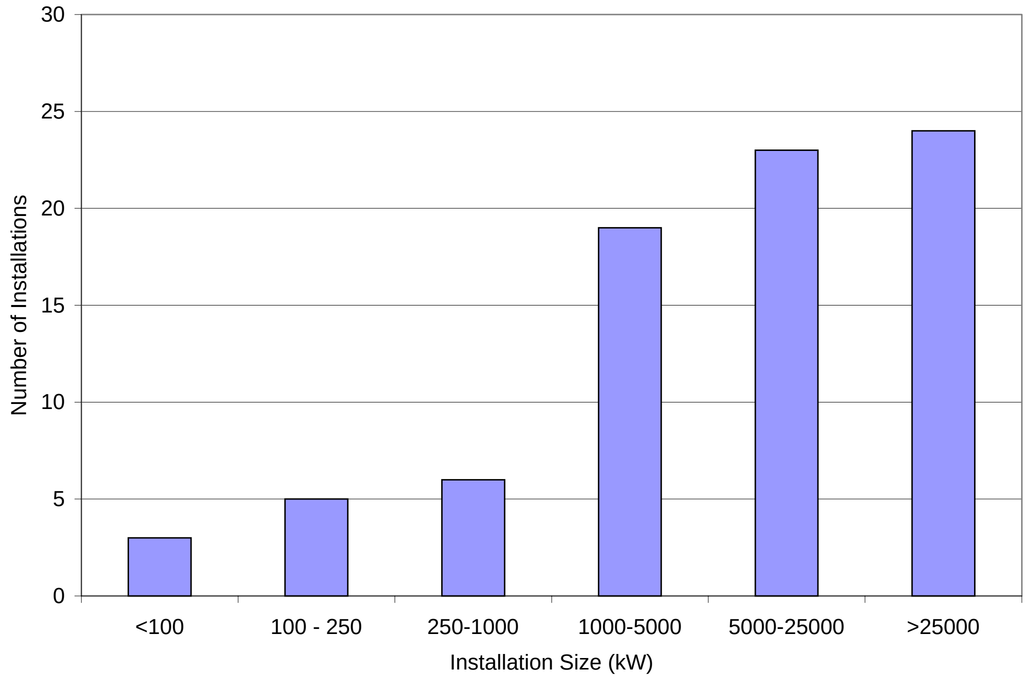

Figure 6 Number of installations per total DER installation electrical output, demonstration and incomplete cases deleted.

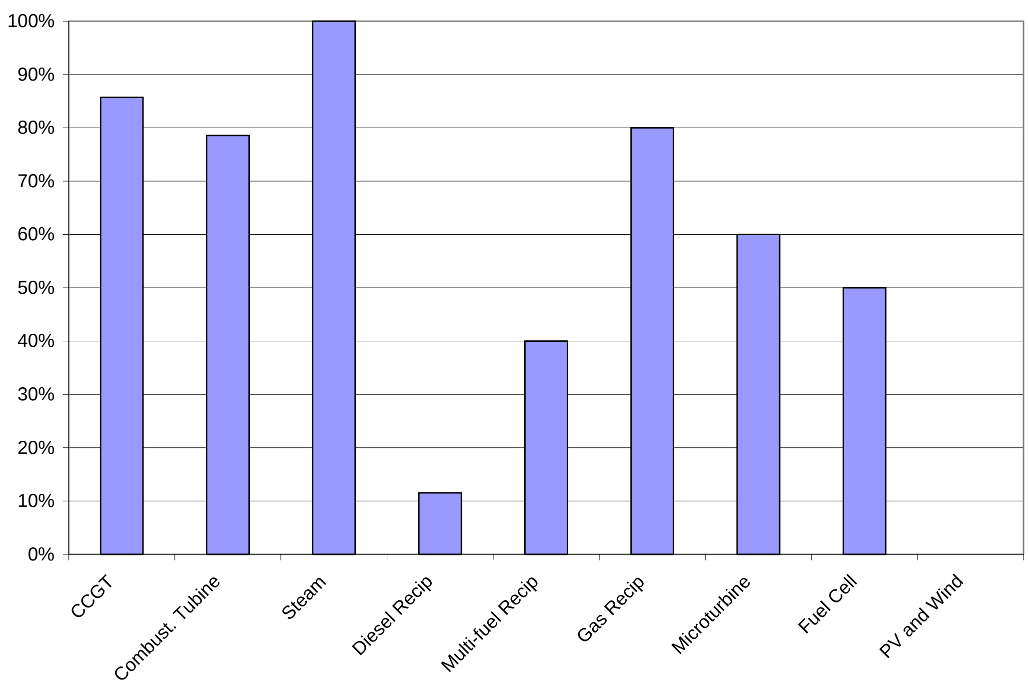

Figure 7 Portion of installations employing cogeneration for each technology type, demonstration and incomplete cases deleted.

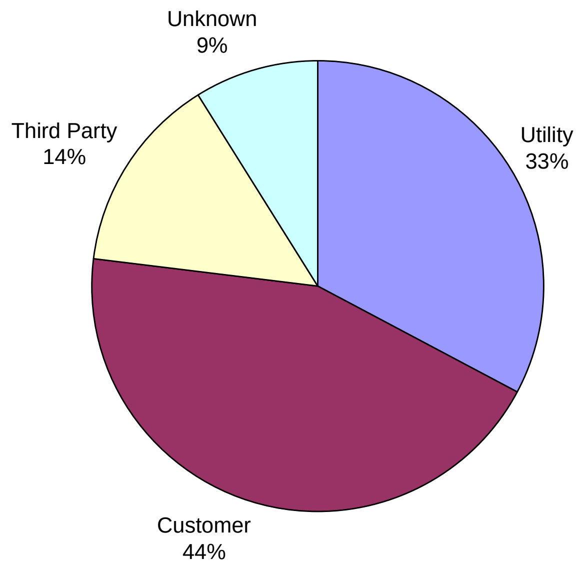

Figure 8 Type of ownership by number of installations, demonstration cases deleted.

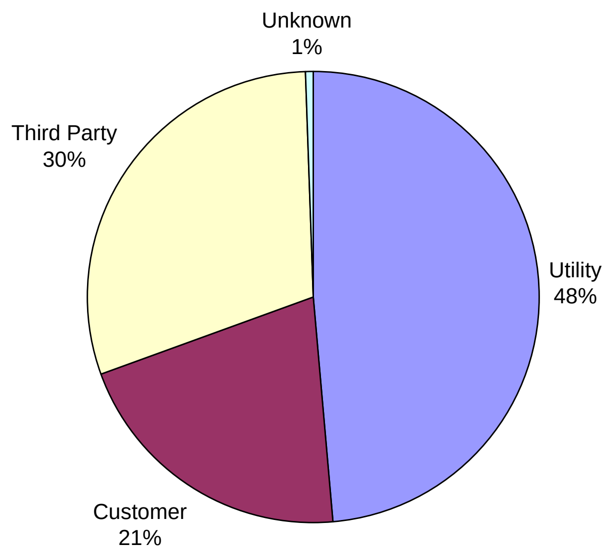

Figure 9 Type of ownership by installed capacity, demonstration cases deleted.

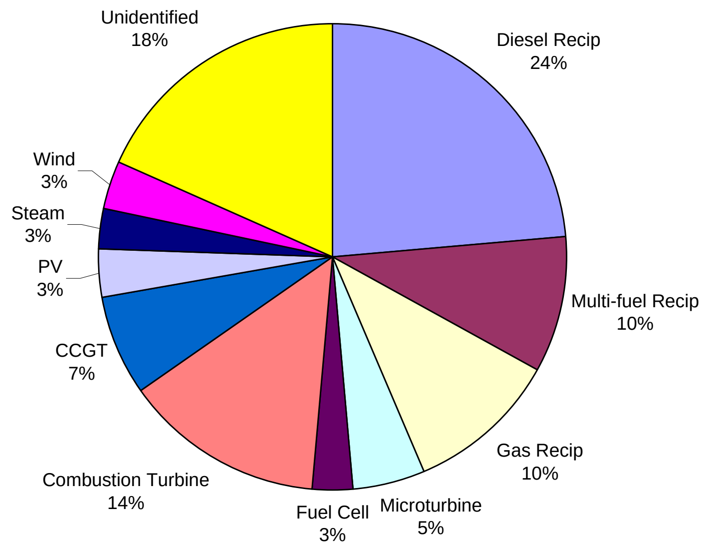

Figure 10 DER Technology by number of installations, demonstration cases deleted.

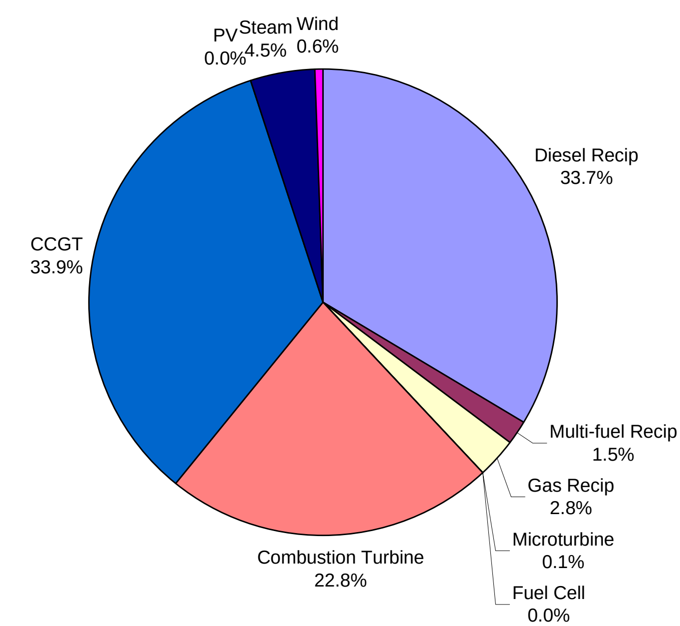

Figure 11 DER Technology breakdown by installed capacity, demonstration cases deleted.

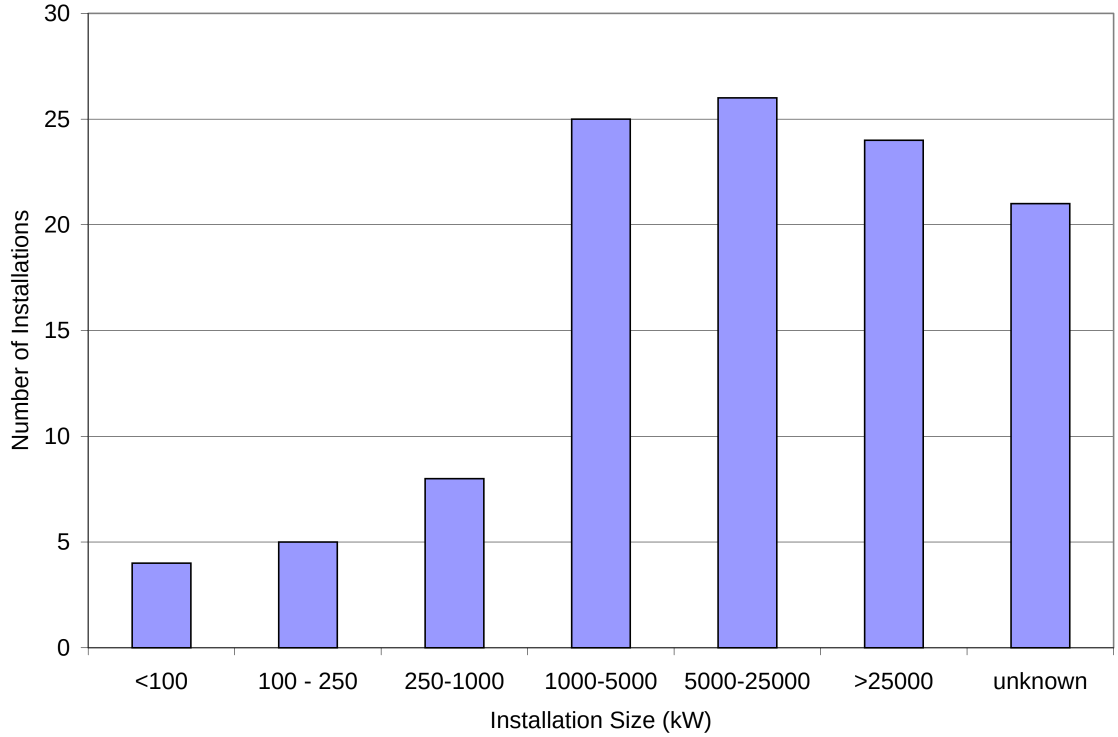

Figure 12 DER Installation size distribution, demonstration cases deleted.

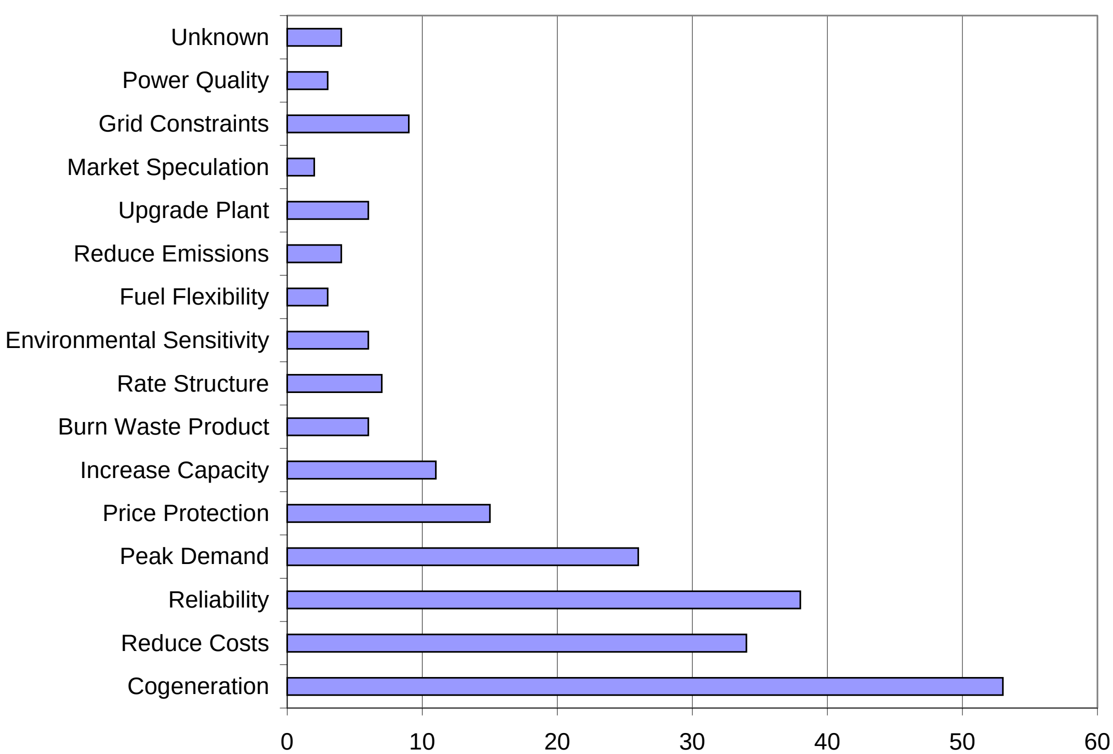

Figure 13 Reasons cited for installing DER, demonstration cases deleted.

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